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RESEARCH PAPER

REML/BLUP to estimate GxE interaction in co-ordinated wheat trials

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Abstract : Significant linear trend has been observed for wheat production under irrigated timely (IT) and late (IL) sown conditions along with marginal improvement for restricted irrigation (RI) timely sown wheat trials for Northern Western Plains Zone of country. Production elevated to the level of 57, 50 and 49q/ha for irrigated timely, late sown and RI timely sown trials. Significant values of intercept at 0.01 per cent for first two conditions along with significant value for third condition. More over significant values (at P< 0.005) of slope for linear trend exhibited by irrigated timely and late sown trials with significant change at large values of probability for remaining condition. Desirable small value of CV had been portrayed by irrigated timely and late sown trials as compared to large value for restricted irrigated condition. Average production was 51.6q/ha, 42.3q/ha and 45.6q/ha in 2008-09 and by the end of period 0.62, 0.91 and 0.04 quintal yield could be added in subsequent trials, respectively.

Key Words : Mixed model analysis, REML, BLUP, FA

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INTRODUCTION

Multi location trials of wheat crop are conducted under coordinated system across the country (Mohan *et al.*, 2017). Salient findings of these trials assist to recommend the cultivation of promising genotypes for specific and general conditions across various agro climatic zones of India (Kleinknecht *et al.*, 2013). Mostly, averages at site and across sites calculated to judge the performance of genotypes. Least squares procedure estimates the genotypes yields for the balanced field designs. However, distribution of error term in field layouts is often more complex as that of in standard linear models analysis (Piepho *et al.*, 2008). Best linear unbiased predictor (BLUP), as a technique for predicting random effects proved numerous applications in field experimentations to estimate fixed and random effects of genotypes, environments and interaction effects (De Pelegrin *et al.*, 2017). This improves *per se* performance of prediction produce as compared to the ordinary least squares approach (Baretta *et al.*, 2017). Mixed models had been utilized as important alternative analytical approaches to overcome limitations of the fixed effects

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approach (Crespo *et al.*, 2018). Moreover, wheat breeders have paid little attention to this important aspect of multi environments testing. Consequently genotypes averages are generally used regard less of the situations.

Restricted maximum likelihood (REML) method had been found a standard to estimate variance components / genetic parameters with working mixed model (Gustavo *et al.*, 2017). For mixed models, the Best Linear Unbiased Predictor (BLUP) is near the phenotypic average observed for the true genotypic value of the individual, which is a property of an accurate estimator (Torres *et al.*, 2015). BLUP can be used for both the selection of superior individuals and the estimation of future generations' gains (Smith *et al.*, 2015). Modeling GxE by factor analytical (FA) had been utilized for large number of crops as this tool uses the leading principal components of the variance-covariance GxE interaction matrix and accounts for the maximum amount of variation with a reduced number of parameters, yielding a more parsimonious variance-covariance structure (Kelly *et al.*, 2007; Burgueno *et al.*, 2008 and Cullis *et al.*, 2014). Need was felt to perform study based mixed effect models that can increase the accuracy of the selection process of wheat genotypes subsequently results in greater genetic improvement.

MATERIAL AND METHODS

North Western Plain Zone of India comprises of the parts of sub-humid Sutlej-Ganga Alluvial Plains and arid western plains, which comprises Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions), Western Uttar Pradesh (except Jhansi division and hilly areas), parts of Jammu and Kashmir (Jammu and Kathua districts) and parts of Himachal Pradesh (Paonta Valley and Una districts).Wheat is cultivated for three broad cultural conditions, *viz.*, timely sown irrigated, late sown irrigated and timely sown restricted irrigation in major wheat zone. The Experimental Design was Randomized Blocks in three replicates. The advanced varietal trials under irrigated timely and late sown with restricted irrigated timely sown conditions were considered during the period 2012-13 to 2017-18 growing seasons in the major locations of the zone. Moreover, the details of genotypes and locations were reflected in table for completeness.

Estimation of the variance parameters carried out by using residual maximum likelihood (REML) along with estimation / prediction of the fixed as well as random

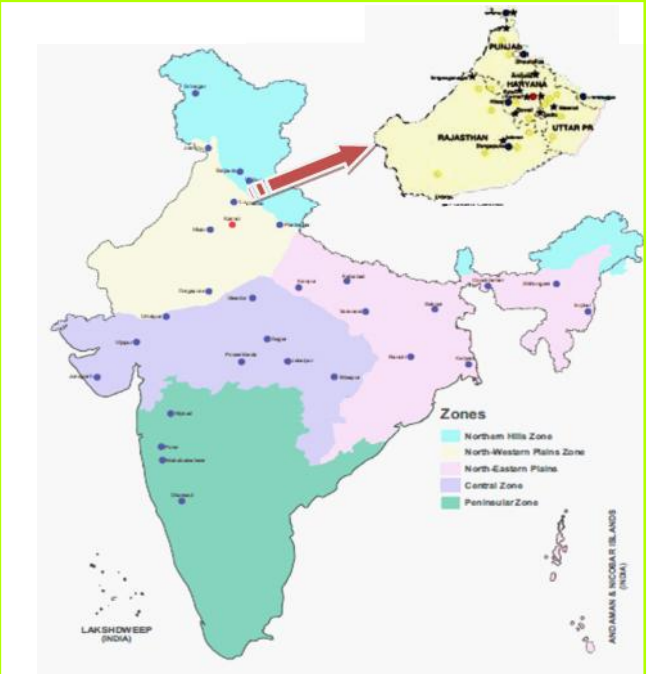

Fig. A : Agro climatics zones for wheat cultivation in country

effects (Eileen *et al.*, 2015). Quite popular and widely cited ASReml-R package was exploited to fit models which use the average information algorithm for REML. Implementation of Factor Analytic approach in ASReml-R package handles the situations of where rank of interaction matrix is of less than full rank. Under Multi Environment Trials, g genotypes were evaluated in e environments and analysed as per model (Resende *et al.*, 2004).

$$y_{ijk} = \mu + \tau_i + \delta_j + (\tau\delta)_{ij} + \gamma(\delta)_{jk} + \varepsilon_{ijk}$$

y_{ijk} yield of k replication of ith genotype in j-th environment; μ overall mean; τ_i Effect of genotype; δ_j Effect of environment; $(\tau\delta)_{ij}$ Interaction effect; $\gamma(\delta)_{jk}$ Effect of k-th replication in j-th environment; ε_{ijk} Random error

i=1,2,3,....g;j=1,2,3,....e;k=1,2,3,....r

RESULTS AND DISCUSSION

Highly significant change in wheat production had been observed during the studied period for irrigated timely, late sown and restricted irrigated timely sown trials in a major wheat producing zone of the country as reflected in ANOVA Tables (4, 5 and 6). Large values

Table 1 : Parentage details of genotypes for irrigated timely sown conditions

2017-18	2016-17	2015-16	2014-15	2014-13	2012-13
UP2981 (CHYAK/PAURAQ)	DBW189 (KACHU#1/4/CROC_1/ AE.SQUARROSA(205)// BORL95/3/2*MILAN/5/ KACHU)	UP2907 (ATTILA*2/STAR //DBW39)	PBW709 (PBW621/HD2967)	PBW697 (DBW1 8/3/WL711-AE OVATA/CS(S)//W171 1 NN/4/DBW18)	HUW 666 (H W2O6/ALTAR84// VE E/M I LAN)
DBW221 (36IBWSN284/22ESWYT 28)	DBW196 (ROLF07*2/KACHU#1)	WH1184 (HD2850/WH147)	PBW707 (FRET2/TU KU RU//FRET2/ 3/M U N IA/C HTO//AMS EL /4/FRET /TU KU RU/FRET2)	TL2995 (TL2608/JNIT141 //JNIT128)	WH1138 (PBW65*2/PASTOR)
DBW222 (KACHU/SAUAL/8/ATTI LA*2/PBW65/6/PVN//CA R422/ANA/5/BOW/CRO W//BUC/PVN/3/YR/4/TR AP#1/7/ATTILA/2*PAST OR)	PBW750 (TOB/ERA//TOB/CNO6 7/3/PLO/4/VEE#5/5/KA UZ/6/FRET2/7/PASTOR //MILAN/KAUZ/3/BAV 92)	UP2903 ((MILAN/S8723O// BABAX)/PBW550)	HD3159 (WBLL1*2/BRAMBLING/ 5/BABAX/LR42//BABAX* 2/4/SNI/TRAP#1/3/KAUZ* 2/TRAP//KAUZ) l I3IKAUZ-2NRAPII KAUZ)	WH1156 (TILHI/PASTOR)	PBW 683 (WH890-AE.UMB. 3732(AMPH.)/ S(S)/ WL711NN/ /3*PBW 343
BRW3792 (PF74354//LD/ALD/4/2*B R12*2/3/JUP//PAR214)	WH1202 (D67.2/PARANA66.270/ /AE.SQ.(320)/3/CUNNI NGHAM)	PBW725 (PBW 621// GLU P RO3*PbW568/3/PBW621)	HD2967© (ALD/CUC//URES/HD2160 M/HD2278)	PBW681 (UP2338/ KALYANSONA)	PBW681 (UP2338/ KALYANSONA)
PBW763 (PBW621/3/YR10/6*AVO CET//4*PBW343/4/2*PB W621/5/PBW621/3/YR15/ 6*AVOCET//4*PBW343/4 /2*PBW621)	HD3226 (GRACKLE/HD2894)	HD3086 © (DBW14/HD 2733//HUW468)	DPW621-50© (KAUZ//ALTAR84/AOS/3/ MILAN/KAUZ/4/HUITES)	DBW95 (K99O8/PBW534)	WH1139 (CHIR/3/SIREN//ALT AR84)
PBW766 (NAC/TH.AC//3*PVN/3/ MIRLO/BUC/4/2*PASTO R/5/KACHU/6/KACHU)	UP2942 (CS/TH.SC//3*PVN/3/M IRLO/BUC/4/URES/JUN //KAUZ/5/HUITES/6/ YANAC/7/CS/ TH.SC /3*PVN/3/MIRLO/BUC/ 4/MILAN/5/TILHI)	HD2967© (ALD/CUC//URES/HD2160 M/HD2278)	WH1105© (MILAN/S87230//BABAX)	HD3128 (VL849/HW5015)	UP2841 (HUW559/PBW527)
DBW233 (CHIBIA//PRLII/CM65531 /3/SKAUZ/BAV92/4/MUN AL#1)	HP1963 (FRET2/TUKURU//FRE T2/3/MUNIA/CHTO//A MSEL/4/FRET2/TUKUR U//FRET2)	WH1105© (MILAN/S87230 //BABAX)	HD3086© (DBW14/HD2733 //HUW468)	WH1157 (MUNIA/ CHTO//AMSEL)	DBW88* (KAUZ//ALTAR84/AO S/3/MILAN/KAUZ/4/H UITES)
HD3226 (GRACKLE/HD2894)	BRW3773(FRANCOLIN #1//WBLL1*2/BRAMBL ING/3/WBLL1*2)	DBW88© (KAUZ//ALTAR84/AOS/3/ MILAN/KAUZ/4/HUITES)	DBW88© (KAUZ//ALTAR84/AOS/3/ MILAN/KAUZ/4/HUITES)	WH1138 (PBW65*2/PASTOR)	HD3086* (DBW14/HD2733//HU W468)

Table 1 : Contd……..

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PBW801 (PBW621/3/Yr10/6*Avocet//4*PBW 343/4/ 2*PBW 621/5/PBW 621/3/Yr 15/6*Avocet// 4*PBW 343/4/2*PBW 621)	HD2967© (ALD/CUC//URES/HD2160M/HD 2278)	PBW677 (PFAU/MILAN/5/CHEN/A.SQUARROSA// BCN/3/VEE#7/BOW/4/PASTOR)	HUW662 (DWR322/HUW300//PBW442/WH576)
PBW800 (HD 2967/4/BW 9250*3// Yr10/6* Avocet/3/ BW 9250*3// Yr15/6* Avocet/5/2*HD 2967)	WH1105© (MILAN/S87230//BABAX)	HD3132 (WH542/UP2425)	HD3109 (SOKOLL/3/PASTOR//HXL7573/2*BAU)
DPW621-50© (KAUZ//ALTAR84/AOS/3/MILAN/ KAUZ/4/HUITES)	DBW88© (KAUZ//ALTAR84/AOS/3/MILA N/KAUZ/4/HUITES)	WH1154 (WH337/HD2255//RAJ3077)	DBW102 (WHEAR/KUKUNA/3/C801/3*BATAVIA//2* WBLL1)
HD3086 © (DBW14/HD2733//HUW468)	HD 3086© (DBW14/HD2733//HUW468)	PBW692 (INQUALAB91*3/TUKURU//DBW18)	DBW101 (CHAP10//2*SERI/RAYON)
HD 2967© (ALD/CUC//URES/HD2160M/HD2 278)		PBW698 (BW9250*3/YR10/6*AVOCET/3/BW9250* 3//YR15/6*AVOCET)	HUW664 (PFAU/SERI.1B//AMAD/3/WAXWING)
DBW 88 © (KAUZ//ALTAR84/AOS/3/MILAN/ KAUZ/4/HUITES)		HD3133 (MILAN/S.8723O//BABAX)	DPW 621-50© (KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/4/H UITES)
WH 1105 © (MILAN/S87230//BABAX)		HUW675 (ALTAR84/K AUZ// MILAN/H UW5 1 O)	HD2967© (ALD/CUC//URES/HD2160M/HD2278)
		K1204 (K8434/PBW343)	DBW 17© (CMH79A.95/3*CNO79//RAJ3777)
		PBW695 (PSN/BOW//MILAN/3/2*BERKUT)	WH1105(I) © (MILAN/S87230//BABAX)
		HUW666 (H UW2O6/ALTAR84//VE E/M I LAN)	
		HD2967© (ALD/CUC//URES/HD2160M/HD2278)	
		DPW621-50© (KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/ 4/HUITES)	
		WH1105© (MILAN/S87230//BABAX)	
		DBW88(I) © (KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/ 4/HUITES)	
		HD 3086(I) © (DBW14/HD2733//HUW468)	

Table 2: Parentage details of genotypes for irrigated late sown conditions

2017-18	2016-17	2015-16	2014-15	2014-13	2012-13
PBW 771 (PBW550//YR15/6* AVOCET/3/2* PBW550)	DBW 173 (KAUZ/AA//KAUZ// PBW602)	DBW173 (KAUZ/AA//KAUZ //PBW602)	HI1604 (PFAU/SERI.1 B//AMAD/ 3/WAXWING/4/BABAX/LR42/ /BABAX*2/3/KUKURU)	HD3139 (WBLL 1 //U P2338*2/VIVITSI)	K1114 (HP1731/HUW234)
PBW752 (PBW621/4/PBW343// YR10/6*AVOCET/3/3 *PBW343/5/PBW621)	PBW752 (PBW621/4/PBW343// YR10/6*AVOCET/3/3* PBW343/5/PBW621)	DBW172 (R9819/R9883 //DBW17)	DBW148 (BHRIKUTI/ 35thIBWSN325)	PBW703 (BW9250*3/YR10/6*AV OCET/3/BW9250*3//YR1 5/6*AVOCET)	HUW668 (UP2530/UP2425// WI10785/RAJ3765)
PBW773 (FRANCOLIN#1*2/K IRITATI)	HI1617 (BAJ#1*2/HUIRIVIS#1)	DBW90© (HUW468/WH730)	PBW716 (HD2967/7/CAL/NH//H567.71/3 /SERI/4/CAL/NH//H567.71/5/2* KAUZ/6/PASTOR)	PBW702 (PBW533//YR15/6*AVO CET/3/PBW533)	NIAW1951 (HD2781/NIAW301)
DBW237 (NAC/TH/AC//3*PVN /3/MIRLO/BUC/4/2*P ASTOR/5/KACHU/6/ KACHU)	HD3059© (KAUZ//ALTAR84/AO S/3/MILAN/KAUZ/4/H UITES)	WH1124© (MUNIA/CHTO //AMSEL)	HUW688 (ATTI LA/PASTOR //H P 1 73 1)	DBW128 (SITE/MO//PASTOR /3/TILHI)	HD3091* (PICUS/3/KAUZ*2/ BOW//KAUZ/4/TILHI)
WH1124© (MUNIA/CHTO//AM SEL)	DBW90© (HUW468/WH730)	HD3059© (KAUZ//ALTAR84/ AOS/3/MILAN/KA UZ/4/HUITES)	K1314 (HD2402/K8565)	WH1129* (CS/TH.CS//3*PVN/3/MI RLO/BUC/4/MILAN/5/TI LHI)	WH1128 (PRL/2*PASTOR/4/CHOIX/ST AR/3/HE1/3*CNO79//2*SERI)
DBW90 © (HUW468/WH730)	WH1021© (NYOT95/SONAK)	WH1021© (NYOT95/SONAK)	PBW719 (UP2556/PBW543)	WH1021© (NYOT95/SONAK)	WH1130 (PRL/2*PASTOR/4/CHOIX/ST AR/3/HE1*CNO79)
HD3059© (KAUZ//ALTAR84/A OS/3/MILAN/KAUZ/ 4/HUITES)	WH1124© (MUNIA/CHTO//AMS EL)		DBW150 (DBW1 6/GW322)	HD3059© (KAUZ//ALTAR84/AOS/ 3/MILAN/KAUZ/ 4/HUITES)	WH1124* (MUNIA/CHTO //AMSEL)
WH1021© (NYOT95/SONAK)			UP2883 ((KAUZ//ALTAR84/AOS/3/M I LAN /KAUZ/4/HUITES)/ PBW 502)	PBW590© (WH594/RAJ3814 //W485)	HD3119 (TILHI/PASTOR)
DBW173 (I) © (KAUZ/AA//KAUZ//P BW602)			HD3165 (HD2824/CBW14)	WH1124(I)© (MUNIA/CHTO //AMSEL)	UP2843 (CPAN4073/UP2382//OPATA/R AYON//KAUZ)
			WH1179 (OASIS/SKAUZ//4* BCN/3/3*PASTOR)	DBW90(I)© (HUW468/WH730)	HD3117 (HD2733/HD2824//DW1278)
			K1312 (PBW343/K0402)		WH1129 (CS/TH.CS//3*PVN/3/MIRLO/ BUC/4/MILAN/5/TILHI)
			K1313 (HUW468/K9107)		DBW90* (HUW468/WH730)
			DBW147 (PBN142/DBW30)		PBW590© (WH594/RAJ3814//W485)
			PBW718 (HD2855/PBW55O//PBW548)		PBW373© (ND/VG1944//KAL/BB/3/YAC O'S'/4/VEE#5'S')
			WH1021© (NYOT95/SONAK)		WH1021© (NYOT95/SONAK)
			WH1124© (MUNIA/CHTO//AMSEL		DBW71 (I) © (PRINIA/UP2425)
			HD3059© (KAUZ//ALTAR84/AOS/3/MIL AN/KAUZ/4/HUITES)		HD3059(I) © (KAUZ//ALTAR84/AOS/3/MIL AN/KAUZ/4/HUITES)
			DBW90© (HUW468/WH730)		

Table 3: Parentage details of genotypes for restricted irrigated timely sown conditions

2017-18	2016-17	2015-16	2014-15	2014-13	2012-13
BRW3806 (NI5439/MACS2496)	HD3237 (HD3016/HD2967)	DBW179 (CNO79//PF70354/MUS/3/PASTOR/4/BAV92/5/FRET2/KUKUNA//FRET2/6/MILAN/KAUZ//PRINIA/3/BAV92) M I LAN/KALZl/PRI N IA/3/BAV92)	MP1277* (GW1901MP1142)	UAS356 (UAS316/K9644//NI5439)	DBW74** (WBLLL*2/BRAMBLING)
HD 3237 (HD3016/HD2967)	HI1619 (W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1)	NW6046 (D67. /PARANA66.270//AE.SQ U ARROSA(320)/3/CUNNINGHAM/4 VORB)	PBW644© (PBW175/HD2643)	MP1277 (GW190/MP1142)	PBW660** (WG6761/WG6798)
HI1620 (NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KACHU/6/KACHU)	HI1620 (NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KACHU/6/KACHU)	PBW737 (GONDO//WBLL1*2/TU KU RU/4/GONDO//SHA5/WEAVER/3/PASTOR)	HD3043© (PJN/BOW//OPATA*2/3CROC_1/A.SQUARROSA (224)//OPATA)	DBW129 (PFAU/MILAN/5/CHEN/A.SQUARROSA(TAUS)//BCN/3VEE#7/BOW/4/PASTOR)	HD3122 (W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1)
DBW252 (PFAU/MILAN/5/CHEN/AE.SQ(TAUS)//BCN/3/VEE#7/BOW/4/PASTOR)	CG1023 (BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA(224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92)	WH1142© (OEN/Ae.Sq.(TAUS)/FCT/3/2* WEAVER)	WH1080© (PRL/*2PASTOR)	PBW706 (MINO/898.97)	WH1142 (OEN/Ae.Sq.(TAUS)/FCT/3/2*WEAVER)
HI1628 (FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/PFAU/WEAVER//BRAMBLING)	MP1318 (ATTILA/3*BCN//BAV92/3/TILHI/5/BAV92/3/PRL/SARA//TSI/VEE#5/4/CROC_1/AE.SQUARROSA(224)//2*OPATA)	HD3043© (PJN/BOW//OPATA*2/3CROC_1/A.SQUARROSA(224)//OPATA)	WH1142(I)© (OEN/Ae.Sq.(TAUS)/FCT/3/2*WEAVER)	WH1142* (OEN/Ae.Sq.(TAUS)/FCT/3/2*WEAVER)	HD3120 (ATTILA*2/PBW65//BERKUT)
NIAW 3170 (SKOLL/ROLF07)	MACS6677 (D67.2/PARANA66.270//AE.SQUARROSA(320)/3/CUNNINGHAM/4/WBLL1*2/TUKURU)	WH1080© (PRL/*2PASTOR)		PBW644© (PBW175/HD2643)	UAS347 (TOB/ERA//TOB/CNO67/3/PLO/4/VEE#5/5/KAUZ/6/FRET2/DWR162)
WH1142 © (OEN/Ae.Sq.(TAUS)/FCT/3/2*WEAVER)	WH1080© (PRL/*2PASTOR)	PBW644© (PBW175/HD2643)		WH1080© (PRL/*2PASTOR)	MP3392 (MP3346/NIAW1548)
WH1080 © (PRL/*2PASTOR)	PBW 644 © (PBW175/HD2643)			HD3043© (PJN/BOW//OPATA*2/3CROC_1/A.SQUARROSA(224)//OPATA)	HD3121 (MILAN//PRL/2*PASTOR/4/CROC_1/Ae.Squarrosa(213)//PGO/3/BAV92))
PBW644 © (PBW175/HD2643)	HD 3043© (PJN/BOW//OPATA*2/3CROC_1/A.SQUARROSA(224)//OPATA)				HUW669 (ALTAR84/HUW206//MILAN)
HD 3043 © (PJN/BOW//OPATA*2/3CROC_1/A.SQUARROSA(224)//OPATA)	WH1142© (OEN/Ae.Sq.(TAUS)/FCT/3/2*WEAVER)				HD3070** (TAM200/TUI/3/URES/JUN//KAUZ)
					C306© (REGENT1974/3*CHZ//*2C591/3/P19/C281)
					PBW175© (HD2160/WG1205)
					HD3043© (PJN/BOW//OPATA*2/3CROC_1/Ae.Squarrosa(224)//OPATA)
					WH1080© (PRL/*2PASTOR)

of F-test statistic observed for irrigated timely and late sown conditions though corresponding small value seen for restricted irrigation timely sown trials. Significant values of intercept at 0.01 per cent for first two conditions along with significant value for third condition. More over significant values (at P< 0.005) of slope for linear trend exhibited by irrigated timely and late sown trials with significant change at large values of probability for remaining condition. Desirable small value of CV had been portrayed by irrigated timely and late sown trials as compared to large value for restricted irrigated condition. Similar observations were recorded for root mean square error values. More or less same trend were seen for standard error for year as dependent factor.

Scatter plots of BLUP's of promising genotypes over the years were plotted to examine the co-efficient of determination (R^2) and linear trend to assess progress in wheat production for irrigated timely, late and restricted irrigated timely sown conditions. Regression analysis for production revealed that under irrigated timely as well as late sown condition, R^2 values were highly significant (P<0.01). Under the restricted irrigated timely-sown conditions, small value of R^2 had seen.

Linear trend in the year-wise wheat production in different conditions revealed an increase in average production of promising genotypes in zone by the end of 2017-18. Production figures elevated to the level of 57q/ha (Fig. 1) for irrigated timely, of 50q/ha (Fig. 3) for irrigated late sown and 49q/ha (Fig. 5) for restricted irrigated timely sown trials. However, in 2012-13, average production was 51.6q/ha 42.3q/ha 45.6q/ha and by the end of period 0.62, 0.91 and 0.04 quintal yield could be added in subsequent trials respectively. Although highest yield levels of 58 q/ha (2016-17), 51 q/ha (2016-17) and

Table 4: ANOVA for irrigated timely sown conditions

Source	SS	MSS	F value	Pr > F	Root MSE	R-Square	Coeff Var	Std error	t value	Pr > |t|
Model	54.21	54.21	9.11	0.0041	2.4395	0.1653	4.5359			
Error	273.76	5.95								
Total	327.97									
Parameter	Estimates									
Intercept								0.8029	64.27	<.0001
Year								0.2062	3.02	0.0041

Table 5: ANOVA for irrigated late sown conditions

Source	SS	MSS	F Value	Pr > F	Root MSE	R-Square	Coeff Var	Std Error	t Value	Pr > |t|
Model	87.58	87.58	17.92	0.0002	2.2105	0.3452	4.8553			
Error	166.15	4.89								
Total	253.73									
Parameter	Estimates									
Intercept								0.8402	50.39	<.0001
Year								0.2157	4.23	0.0002

Table 6: ANOVA for restricted irrigated timely sown conditions

Source	SS	MSS	F value	Pr > F	Root MSE	R-Square	Coeff Var	Std Error	t Value	Pr > |t|
Model	0.17	0.17	0.03	0.8668	2.4130	0.0010	5.2694			
Error	163.03	5.82								
Total	163.19									
Parameter	Estimates									
Intercept								1.0046	45.43	<.0001
Year								0.2579	0.17	0.8668

lowest level nearly 40 q/ha (2014-15) were obtained in irrigated timely, late and restricted irrigated timely sown trials. Low values of CV for irrigated timely and late sown conditions suggested consistent improvement in production levels. More over erratic ups and down observed in restricted irrigated timely sown trials.

Study revealed that during studied period wheat production had progressed nicely in this bigger zone. Fitted straight-line trends by SAS software displayed in corresponding figures indicate that the linear growth was

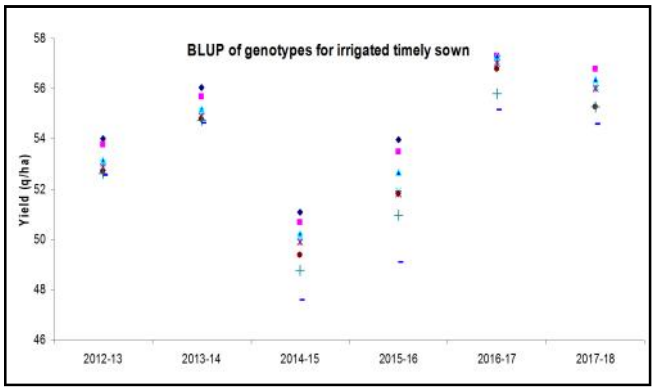

Fig. 1 : Best linear unbiased predictors for promising genotypes for irrigated timely sown conditions

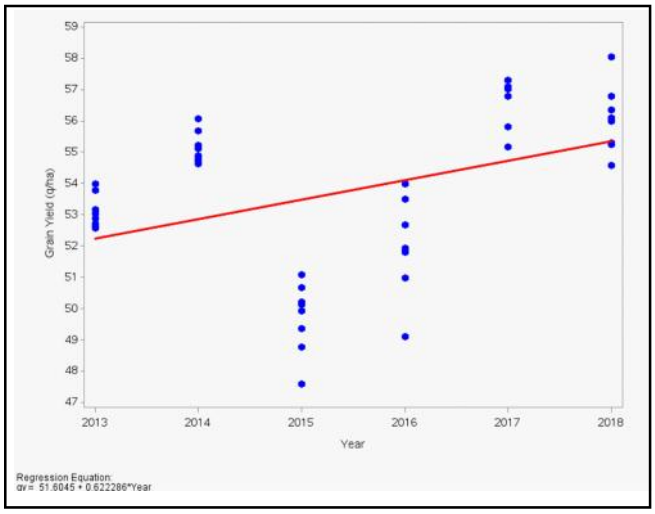

Fig. 2 : Regression analysis of BLUP's for promising genotypes for irrigated timely sown

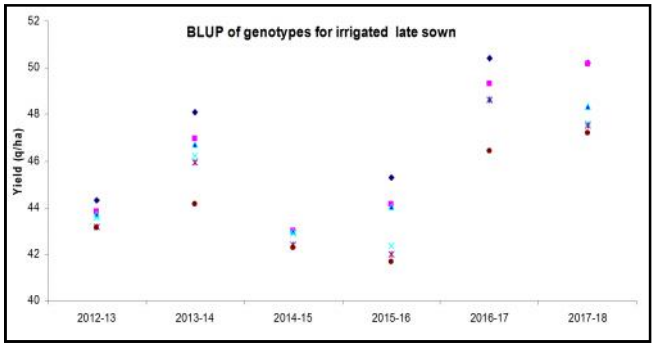

Fig. 3 : Best linear unbiased predictors for promising genotypes for irrigated late sown conditions

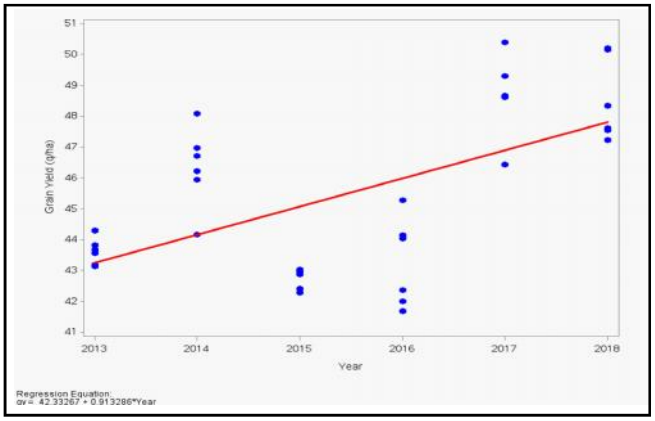

Fig. 4 : Regression analysis of BLUP's for promising genotypes for irrigated late sown

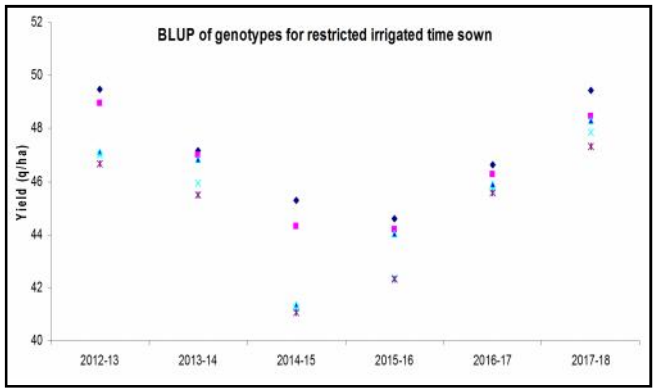

Fig. 5 : Best linear unbiased predictors for promising genotypes for restricted irrigated timely sown conditions

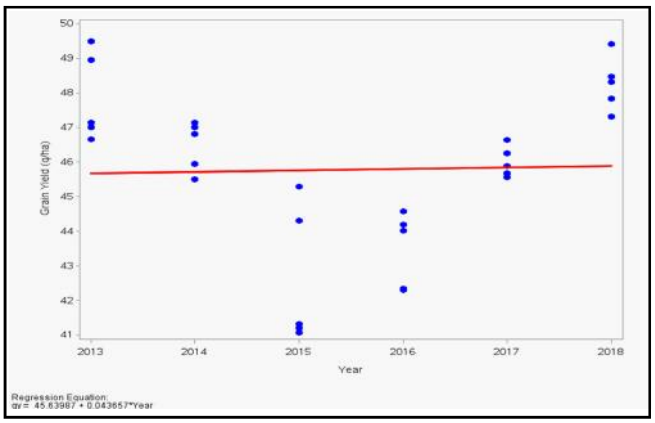

Fig. 6 : Regression analysis of BLUP's for promising genotypes for restricted irrigated timely sown

observed under all sown conditions of the zone. During the year 2008-09, the base yield level was 5160, 4233 and 4564 kg/ha, respectively (as reflected by intercept of the equation). Restricted irrigated conditions of the zone expressed least yield increase over years with small values of R^2.

BLUP analyses of wheat trials showed continuous increase in the grain yield of the genotypes developed by Indian co-ordinated wheat programme. This finding also corroborates with studies on co-ordinated wheat production estimated by BLUE approach (Mohan *et al.*, 2017). More over in present study factor analytic structure of the variance–covariance matrix of GxE interaction was considered to estimate the BLUP's of wheat genotypes (Smith *et al.*, 2015).

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